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THE CONTRIBUTION OF NON-DESTRUCTIVE TESTING FOR THE DEVELOPMENT AND SURVIVAL OF A SOCIETY FROM THE ANTIQUITY TO NOWADAYS

I.N. Prassianakis

National Technical University of Athens, President of HSNT Faculty of Applied Mathematics and Physics Sciences, Department of Mechanics, Laboratory of Strength and Materials, Iroon of Polytechniou Avenue 5, GR-157 73, Zografou Athens, Greece, *E-mail: prasian@central.ntua.gr*

ABSTRACT

It is well known that from the far antiquity to nowadays the development and survival of a society without quality is impossible. Peoples, which have used the quality control in their life, products, structures and services, succeed to create civilization and to survive.
All the technological humanity achievements occur because the peoples knew and used the quality control from the distant antiquity to nowadays.
Objective of this review work is to emphasize, to present and support the simple and common aspect that the Non-Destructive Testing (NDT) contributed significantly on the establishment of a base for the development and the survival of any society from the far antiquity to nowadays.

Keywords: NDT, Ultrasounds, Fracture mechanics, Damage, Mechanical properties

1. Introduction

All the marvelous technological achievements of the human spirit are based on the rapid evolution of the science of the technology as well as on the quality control of materials and structures. The start of Destructive Testing (DT) can be considered the 15th and 16th centuries A.C. when the first tests, such as the tension by L. da Vinci and the bending by G.L.Galileo were executed. The materials' quality control by destructive as well as by NDT methods, as it is well known, was developed and was established as scientific methods much later in the middle of the last century.
But the humanity has to show many works and ultra structures from the distant antiquity. Some samples of them, as the pyramids of Egypt, the Parthenon of Athens, the Colosseum of Rome, the Sinicon Walls of China etc., survive until today because of their very good situation. Although the constructors of these time periods did not know Mechanics and Quality control, they made tough constructions (buildings, monuments, stadiums etc) many of which survive until today, because they knew and applied the NDT.
As many inscriptions confirm it, the ancient Greeks, e.g., used strict specifications in their orders and also a well-organized quality control systems, based on NDT methods, was applied to almost all products in those times for the protection of the consumer as well as the state from the illegitimacy.

All these inscriptions belong to the same century, the 4^{th} B.C. century, the time period in which in ancient Greece a rapid development of Greek civilization took place. It is the well known Golden Season of Pericleous, of a great Greek worldwide known leader, in which period a high level progression noticed in many fields, such as in the democracy, the philosophy, the architecture, the technology and the great technical works.
Thus, the opinion that in well organized with developed civilization societies, developed technology is also observed, is confirmed. Culture and technology that is to say keep pace.
In nowadays ultra-constructions, such as airplanes, ships, trains, spaceships etc work safely because they are tested using NDT methods.
By comparing these two times periods, the far antiquity and the nowadays, the only remarkable difference is that in the first one the NDT was applied by subjective way, while in the latest the same testing is taking place by objective way, using high technology means.
The aim of this paper is the presentation of the historical and scientific truth, which is that the NDT was applied for testing materials and constructions, before the appearance of the DT and also that this way of materials testing was known and was applied by the people, in the far antiquity thousands years ago and on the other hand that the contemporary technological civilization mainly based on the non destructive way of materials testing.
Similar information should also exist in other populations. This paper may constitute a challenge for the execution of relative research concerning other ancient civilizations.

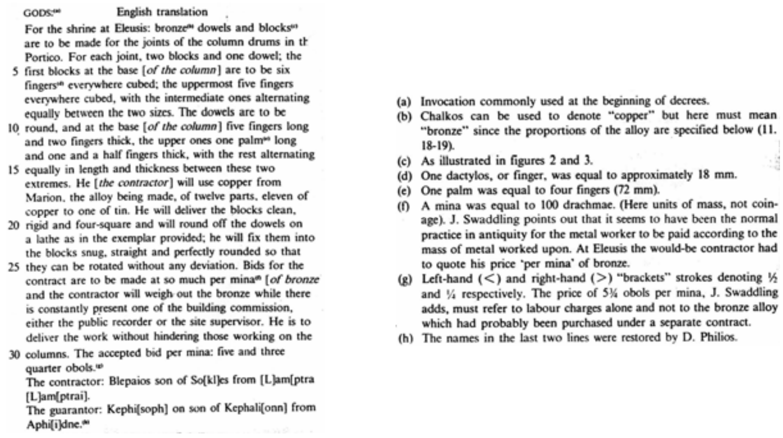
2. Non destructive testing in distant antiquity in ancient Greece

The ancient Greeks were "technological" population. They considered, as it is reported in their Mythology, the Technology (that is to say artistic wisdom) and the Energy (that is to say the fire) as gifts of divine forces to the human gender, immediately afterwards the Creation.
For each marketable good, as for the technological products of ancient Greeks, the production followed the qualitative control. In this direction the historical research is not still enough rich.
“Lydia Lithos", e.g., was a black hard stone and constituted one from the objects with which ancient Greeks by engraving checked the cleanliness of the golden and silver currencies, jewels, alloys and other objects. Still the ancient Greeks for the quality control of these materials used the NDT methods via the five human senses.
Based on historical and scientific information, that the archaeological spade and the scientific research have brought in the light, Varoufakis [1], we are led to the conclusion that the ancient Greeks, 2500 years ago, knew and also applied the qualitative control in the materials that they used. For this reason, on the other hand, many of their creations are saved in a very good situation up today.
In the antiquity the destructive testing was not known, as it was developed after the 15th A.C. century. On the other hand, as it is also confirmed by many ancient Greek inscriptions, the NDT must would be applied by subjective way, that is to say with the help of the five human senses (sight, hearing, touch, smell and taste) with which the Mother Nature has dowered us, as also the modern technology and other relative sciences had not been discovered in that time period, Varoufakis [2].
These inscriptions, which constitute regulations that the ancient Greeks used for the qualitative control of materials are engraved, mainly, in marble plates and they have been found by the archaeologists in excavations that have been carried out in regions where the ancient Greek culture was developed, Prassianakis [3]. Today they are found in various Greek museums and the most important from these are described in the following three sections.

2.1 The inscription of Eleusis

The most important is the inscription of the Eleusis Fig. 1(a). It was found by D. Philios in 1893 in the small town of Eleusis, which is located 15 Km west of Athens city and is inscribed on a white marble stele of dimensions $(51\times29\times6)cm^3$, around 360 B.C. The text appearing in Fig. 1(b), in English translation, constitutes a standard with very strict technical specifications. It concerns the manufacture of bronze fittings known as empolia and poloi, Fig. 2(a), to be used in the erection of the columns of the Philonian Stoa, a portico placed in front of the much older temple of Eleusis, Fig. 2(b), the well known Telestirion, Varoufakis [2].

(a)



GODS:[a] English translation

For the shrine at Eleusis: bronze[b] dowels and blocks[c] are to be made for the joints of the column drums in th Portico. For each joint, two blocks and one dowel; the first blocks at the base [*of the column*] are to be six fingers[d] everywhere cubed; the uppermost five fingers everywhere cubed, with the intermediate ones alternating equally between the two sizes. The dowels are to be round, and at the base [*of the column*] five fingers long and two fingers thick, the upper ones one palm[e] long and one and a half fingers thick, with the rest alternating equally in length and thickness between these two extremes. He [*the contractor*] will use copper from Marion, the alloy being made, of twelve parts, eleven of copper to one of tin. He will deliver the blocks clean, rigid and four-square and will round off the dowels on a lathe as in the exemplar provided; he will fix them into the blocks snug, straight and perfectly rounded so that they can be rotated without any deviation. Bids for the contract are to be made at so much per mina[f] [*of bronze* and the contractor will weigh out the bronze while there is constantly present one of the building commission, either the public recorder or the site supervisor. He is to deliver the work without hindering those working on the columns. The accepted bid per mina: five and three quarter obols.[g]

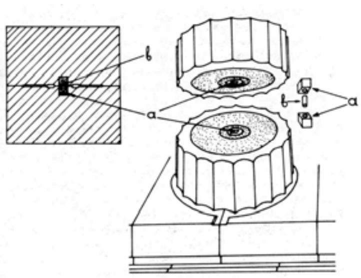
The contractor: Blepaios son of So[kl]es from [L]am[ptra [L]am[ptrai].

The guarantor: Kephi[soph] on son of Kephali[onn] from Aphi[i]dne.[h]

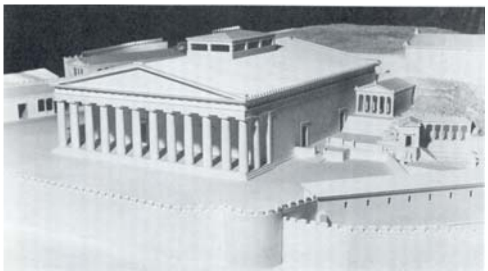
(a) Invocation commonly used at the beginning of decrees.
(b) Chalkos can be used to denote "copper" but here must mean "bronze" since the proportions of the alloy are specified below (11. 18-19).
(c) As illustrated in figures 2 and 3.
(d) One dactylos, or finger, was equal to approximately 18 mm.
(e) One palm was equal to four fingers (72 mm).
(f) A mina was equal to 100 drachmae. (Here units of mass, not coinage). J. Swaddling points out that it seems to have been the normal practice in antiquity for the metal worker to be paid according to the mass of metal worked upon. At Eleusis the would-be contractor had to quote his price 'per mina' of bronze.
(g) Left-hand (<) and right-hand (>) "brackets" strokes denoting ½ and ¼ respectively. The price of 5¾ obols per mina, J. Swaddling adds, must refer to labour charges alone and not to the bronze alloy which had probably been purchased under a separate contract.
(h) The names in the last two lines were restored by D. Philios.

(b)

Fig. 1: The marble inscription of Eleusis (a), and its English translation (b).



(a)



(b)

Fig. 2: The bronze fittings (a) (empolia a(a) and poloi a(b)) and the Temple the Telestirion and the Philonian Stoa, of Eleusis (b).

It is worth noting that it was given the contractor of the project specific instructions about the origin and the chemical composition of the copper-tin alloy, which was to be used and also the shape and exact sizes of the required fittings were specified. It reports that the bronze and the fittings should be produced in the Marion of Cyprus (today named Arsinoi) and that in the 12 parts must be contained 11 copper and 1 tin. At that time the above-mentioned inscription is considered as the oldest ancient European standard discovered so far.

2.2 The Athenian law on silver coinage

The stele of Fig. 3(a) of dimensions $(127\times46\times13)cm^3$, regard the Athenian law on silver coinage belongs to the beginning of the 4^{th} century B.C. and constitutes a "directive" regarding the quality control of silver in general, and more specifically the Athenian silver currency. It was discovered during the ancient Agora excavations on 1970.

In this inscription the following important points are noted: a) The law required that the silver currency should be tested by a skilled public officer. b) The testers and the sellers of goods were to be severely punished in case the former were reluctant to test the silver coins brought to them, and the latter if they did not accept coins certified to be genuine. c) The law states that a tester existed in the city of Athens, and one was newly installed in Piraeus. d) The new law in force cancels and replaces existing previous decrees.

(a) (b) (c) (d)

Fig. 3: The Athenian law (a), a pure silver Athenian coin of 5th century B.C. (b), a counterfeit Athenian coin of the archaic period cut across of the 6th century B.C. (c) and a copper silver plated Athenian coin of 5th century B.C. (d).

In Fig. 3(b) there is a pure silver Athenian coin of 5th century B.C. in Fig. 3(c) there is a counterfeit coin of the late archaic period cut across, strengthens this view, while Fig. 3(d) shows a case of counterfeit coin of the end of the 5th B.C. century.

2.3 The inscriptions of Thassos

There are, finally, three inscriptions of the 5th century B.C., which are kept at the small museum of the Thassos, a small island of the north Aegean. Their text mentions the following three very important directives, concerning the quality control of wine: a) The purchase of wine would have been valid, only, if the large jars (pithos) of wine had been sealed with a quality mark, b) A heavy penalty should be imposed on those importing foreign wine in the area of the island of Thassos, and c) The penalties would have been equivalent to those imposed in the case of “watering the wine”.

The latter is extremely important since it reveals the existence of another law, unfortunately not yet found, which would have specified the quality control of wine, Varoufakis [2]. The conclusion is that the testers in ancient Greek must have used their senses sight, smell and taste for testing the wine.

2.4 Possible quality control procedures of testing metals in antiquity

The quality control of metals alloys should be based on the NDT methods. They should be used reference specimens with different contents in the various metals, Varoufakis [2]. Then the tester with the help of NDT methods, that is to say the sight, hearing and with engraving, comparing the unknown content of alloy with the standard reference blocks would realize easily the composition of the unknown alloy and consequently the existence of illegitimacy.

In antiquity, the ancients should have applied a simple empirical, most probably non-destructive procedure. Contemporary testers, dealing with gold and silver coins suggested, that the ancients could test the genuineness of silver and gold coins by applying, as they say, their three senses: sight, touch and hearing. First, they observe the coin carefully, then they touch it with their very sensitive fingers, they feel the weight when keeping it in their first, and finally they let it drop on a hard surface and hear the sound of its ringing.

Regarding gold, it is well known that its purity or its composition was determined by the common test of the touchstone (Lydian stone). It is the oldest colorimetric non-destructive assaying in use since the antiquity. The test is based on the comparison of rubbing a gold object of unknown composition and those left by a series of gold standards of certified composition.

The testing of bronze composition must be done in a similar way. A color comparison between the bronze supplied by the contractor and a series of standards of copper and copper-tin alloys of know composition reference specimens would have been a possible testing procedure.
The message from the distant antiquity is that the ancient Greeks used strict specifications in their orders and also strict control of quality of alloys of copper, because, if there is not a control, the specifications would not have any value and the danger for illegitimacy would be serious.

3. NDT in nowadays and some of their advanced applications

NDT has been defined as comprising those test methods used to examine an object, material or system without impairing its future usefulness. NDT is a branch of the materials sciences that is concerned with all aspects of the uniformity, quality and serviceability of materials and structures. The science of NDT incorporates all the technology for detection and measurement of significant properties, including discontinuities, in items ranging from research specimens to finished hardware and products. NDT has become an increasingly vital factor in the effective conduct of research, development, design and manufacturing programs and has been widely used for studding of structural materials, Krautkramer [4] and Prassianakis [5].
The international community on NDT adopted a system that classifies the methods into six major categories: visual, penetrating, radiation, magnetic-electrical, mechanical vibration, thermal and chemical-electrochemical. The list of NDT applications is endless. It exist a wide range of NDT methods and the most common are the Visual, the Radiographic, the Liquid Penetrant, the Magnetic Particle, the Eddy Current, the Acoustic Emission, the Thermographic and the Ultrasonic Testing (UT).
Using NDT methods the defects, discontinuities, the dimensions of the engineering materials as well as many of their mechanical properties, such as the dynamic elastic moduli E', G', ν', the attenuation coefficient α, the damage parameter D, the fracture strength σ_f and the order of singularity λ of materials can be easily determined. An application of NDT methods of great importance is the testing of monuments and various archeological objects where the destructive way for testing is absolutely forbidden.
Modern nondestructive tests are used by manufacturers in order to: ensure product integrity, and in turn, reliability, avoid failures, prevent accidents and save human life, make a profit for the user, ensure customer satisfaction, aid in better product design, control manufacturing processes, lower manufacturing costs, and maintain uniform quality level.
Almost every product, no matter its size, location and material composition can in nowadays be inspected using one of the existing NDT methods. Some advanced applications of the ultrasonic NDT method for testing engineering materials are the following:

3.1 The ultrasonic evaluation of materials elastic moduli

Using the velocities of longitudinal c_ℓ and transverse c_t elastic waves and the density ρ of a material, one can evaluate the corresponding dynamic modulus of elasticity E', the shear modulus G' and the Poisson's ratio ν', from the eqs. (1), according to [7].

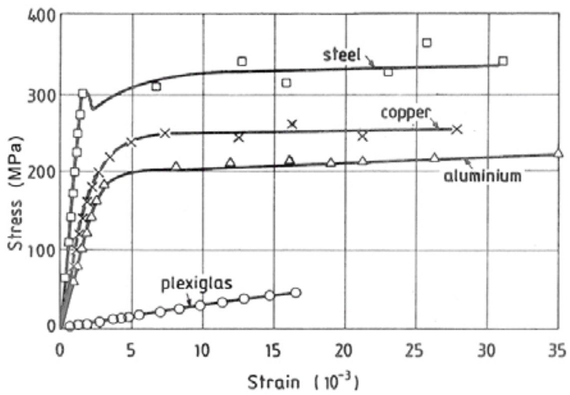
$$E' = 4\rho c_t^2 \frac{\frac{3}{4} - \left(c_t/c_\ell\right)^2}{1-\left(c_t/c_\ell\right)^2}, G' = \rho c_t^2, \nu' = \frac{\frac{1}{2}\left(\frac{c_\ell}{c_t}\right)^2 - 1}{\left(\frac{c_\ell}{c_t}\right)^2 - 1} \tag{1}$$

These moduli of elasticity are strongly affected by the frequency f of the used elastic waves as well as from the viscosity n and the elasticity E of the materials, as comes out from the following basic relation (2) given by Perepechko [6] and has been verified experimentally by Prassianakis [7],

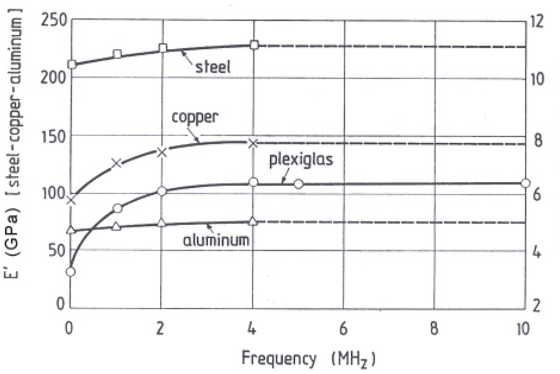
$$c^2 = c_0^2 + \int_0^\infty \frac{H(\tau)\omega^2\tau^2}{\rho(1+\omega^2\tau^2)} d\tau \tag{2}$$

where $\omega = 2\pi f$, $\tau = n/E$ is the relaxation time, $H(\tau)$ is the density of the spectrum of relaxation times and c_0 is the limit velocity corresponding to the static modulus of elasticity for $f=0$. According to eq. (2), the determined elastic moduli using ultrasounds are always higher than the corresponding static moduli, this depending on the wave's frequency as well as on the kind of material tested.

Using ultrasounds the dynamic elastic moduli E', G', and ν' of steel, copper, aluminium and Plexiglas were determined, Prassianakis [7]. Fig. 4(a) shows the experimental stress-strain curves of these materials, from which the static moduli E, G, ν were evaluated and the results are shown on Figs. 4(b)-(d) for frequency $f = 0$. Figs. 4(b)-(d) shows the variation of the dynamic moduli of elasticity versus the frequency, changing from the value $f = 0$ up to $f = 10MHz$. From these diagrams the influence of relaxation time τ as well as of the frequency f on the moduli of elasticity arise. The more elastic the material is (the relaxation time tends to zero, $\tau \to 0$), and/or the frequency of the elastic waves tends to zero $(f \to 0)$ the elastic moduli tend to their limiting value, which are equal to the corresponding static moduli.



(a)



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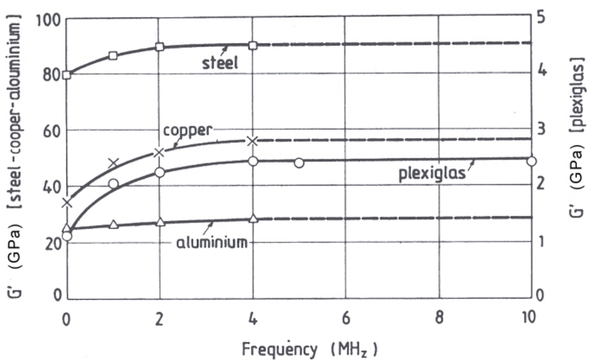
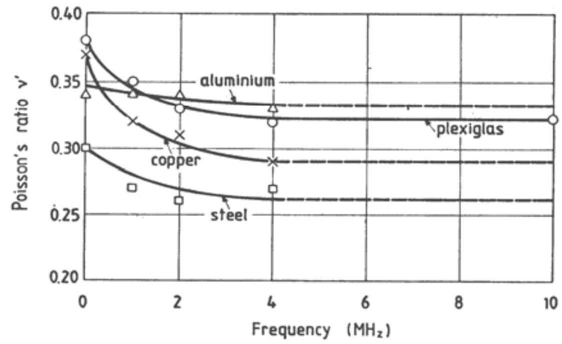


(c)



(d)

Fig. 4: Stress-strain curves (a), and dymanic moduli of elasticity (b), (c) and (d) versus the frequency of ultrasonic wave.

3.2. Determination of the attenuation coefficient using ultrasounds and its correlation to the order of singularity

The attenuation coefficient α, is evaluated using the following well known relationship (2), [8,9]:

$$\alpha = \tfrac{20}{2d} \log \frac{H_0}{H} \tag{3}$$

where d is the specimen thickness and H_0 and H are the two successive back wall echo (the first and the second) heights, measured on the screen of the ultrasonic equipment.

Measuring the attenuation change in front of various notch tips using eq. (3), one can correlate the order of singularity with the ultrasonic wave's attenuation, Prassianakis [18].

For the examination of the singularity influence on the ultrasonic wave attenuation, notched prismatic specimens made from Plexiglas were tested in tension until fracture, Prassianakis [9]. The angles of notches were φ=0°, 45°, 60° and 180°. All used specimens had the same dimensions (30.0x5.0x1.0) cm^3 and had been tested in ambient conditions. The length of the notches was 1.0cm. The measurement of the attenuation change $\Delta\alpha$ was made in the area close to and in front of the notch tip, with the probe placed transversely on the specimen. All measurements were executed with ultrasonic longitudinal wave, the frequency of which was 1MHz. The results are shown in Fig. 5. From the curves of this figure we observe that as the angle of the notch decreases from the value equal to φ=180° to the value equal to φ=0° (the order of singularity increases from the value of λ=0 to the value equal to λ= –0.5) the rupture load decreases and the attenuation coefficient increases. The decrease of rupture load with the decrease of the notch angle is due to the increase of the order of singularity at the examined area.

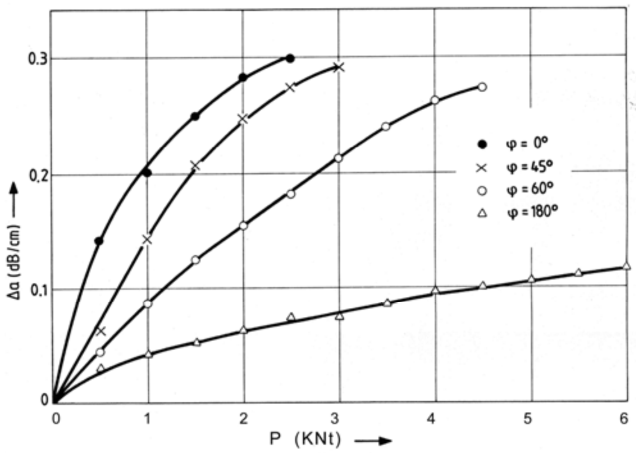


Fig. 5: The variation of attenuation $\Delta\alpha$ versus the applied load for four distinct values of V-notch Plexiglas specimen angle.

3.3 The ultrasonic determination of the damage parameter

The damage parameter D is defined as the effective surface density of micro-cracks and cavities in any plane of a representative volume element, by the eq. (4), according to Fig. 6, Kachanov [10]. It can be also determined using ultrasounds by the relationship (5), introduced by Prassianakis [8].

$$\mathrm{D} = \frac{\mathrm{A}_\alpha - \mathrm{A}_\varepsilon}{\mathrm{A}_\alpha} = \frac{\mathrm{A}_\mathrm{d}}{\mathrm{A}_\alpha} \tag{4}$$

$$D = \frac{H_0 - H}{H_0} \tag{5}$$

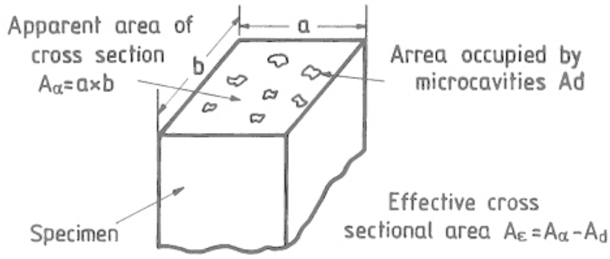
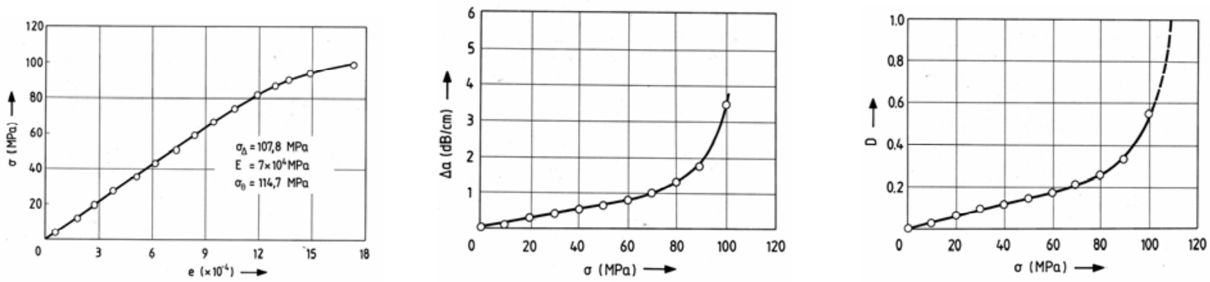


Fig. 6: A typical damaged cross-section.

The damage parameter D was determined using ultrasounds from the eq. (5), for the aluminium, the marble and the concrete. The frequency of the ultrasonic waves used was 2MHz, for the examination of aluminium and marble and 1MHz for the examination of concrete.
First prismatic aluminium specimens were tested in simple tension until their fracture, Prassianakis [8]. During the experiments the stress-strain curves, the change of attenuation Δa and the damage D (eqs. (3) and (5)) as a function of the tension stress level were determined.
The stress-strain curve $\sigma = f(e)$ of this material as well as the yield σ_{Δ} and fracture σ_{Θ} stresses and the modulus of elasticity are shown in Fig. 7(a). In Fig. 7(b) is shown the change of the attenuation coefficient $\Delta\alpha$ and in Fig. 7(c) the change of damage parameter D, versus the applied tension stress σ, up to the fracture of the aluminium specimens.

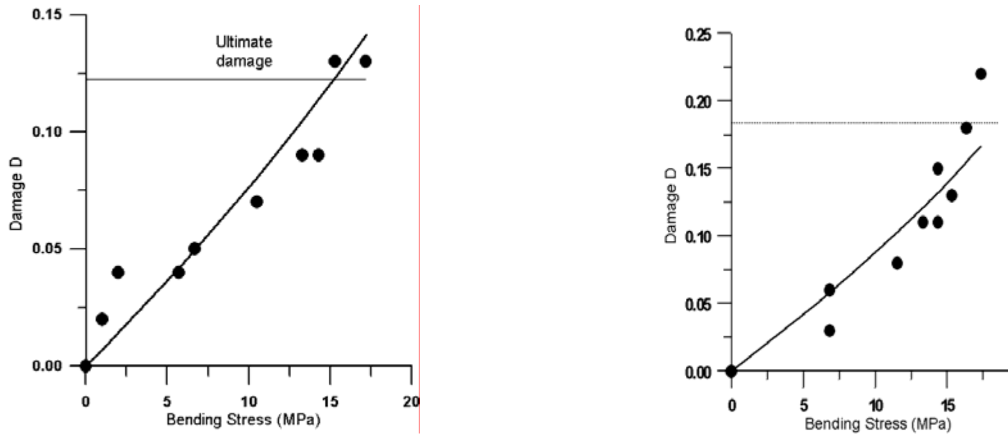


(a) (b) (c)

Fig. 7: Stress-strain curve of the aluminium from tension test (a), the variation of attenuation $\Delta\alpha$ (b) and the damage D (c) versus the applied tension stress σ in aluminium.

Thus, as the damage is insignificant at small stresses, so also the values of attenuation and of the corresponding strain are insignificant. But near the yielding point of the material, where the material passes slowly from elastic to plastic deformation, many defects are appeared and the damage suddenly takes significant values, as do the other two quantities $\Delta\alpha$ and e.
Furthermore the ultrasonic measurements of damage on marble were executed on prismatic Dionysos-Pentelikon famous Greek marble beams, with dimensions 100x25x25cm^3, subjected in three point bending, Prassianakis [11]. During the loading procedure the damage was experimentally measured in both tension region of the specimens as well as in the compression one using eq. (5). These results, as a function of the bending stress level, are presented in Fig. 8. The dots correspond to the experimental results using ultrasounds and the continuous lines to the theoretical results, for the extensional and for the compression regions.
Concerning the values of the damage parameter it can be seen that in the compression region they are of negative sign while in the tension one they are positive. This behavior can be easily explained, if one takes into account the fact that in the compression region the "active" area increases during loading since up to a certain load level the preexisting microcracks close, as oppose to the tension region, in which from the very first load stages the number of microcracks increases and the pre-existing ones become greater. As a result, the height of the reflected sound wave monitored on the screen H, increases in the compressed region exceeding the initial one

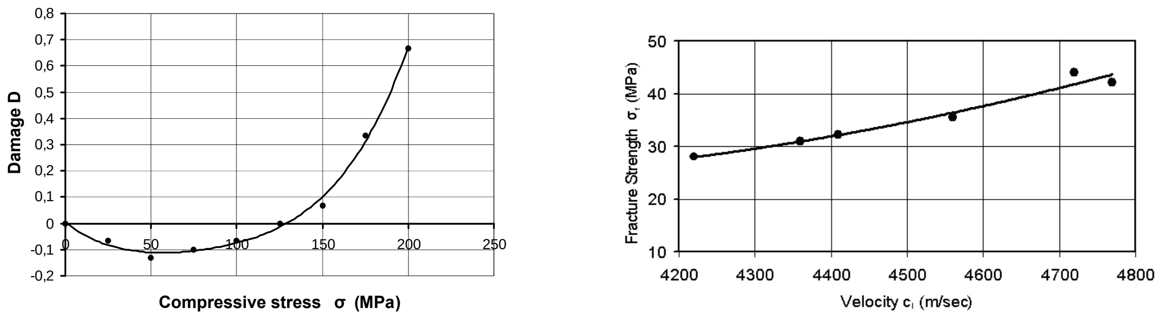
H_0 corresponding to the respective quantity for the unloaded condition, yielding negative damage values, while the opposite take place in the extension region.



(a) (b)

Fig. 8: Experimental, dots, and theoretical, continuous lines, dependence of the damage parameter developed in extensional region (a) and in the compressive region, were the damage is taking negative values (b) of marble beam, under three-point bending.

Finally the damage parameter D was evaluated in the compression region of the cross section, during the compressive loading of concrete cubic specimens, which as a function of the compressive stress level σ has been presented in Fig. 9(a), Prassianakis [12]. From this figure arises that for relatively low stress levels the damage values decrease taking negative values. But as the compression stress level increases, the damage also increases taking higher positive values.



(a) (b)

Fig. 9: The variation of ultrasonic longitudinal waves damage D, for concrete cubic specimens, versus the compressive stress σ (a) and the variation of concrete compressive fracture stress σ_f, versus the ultrasonic longitudinal wave's velocity c_l, (b).

For the explanation of this complex behavior of damage evolution versus stress level, the behavior as well as the mechanisms and failure mode of the concrete during its compressive loading from low stress levels until its fracture, must be considered. At the first step of the compressive loading, concrete behaves as a homogeneous brittle material whose active area increases during loading, since up to a certain load level the pre-existing microcracks close. As a result the amplitude, H, of the reflected sound wave monitored on the screen increases exceeding the initial one, Ho, yielding negative damage values. But as the loading increases and the specimen prepared for its fracture, under the action of shear stresses, which are located in inclined planes under 45^o, the number of microcracks increases and the pre-existing ones become greater. As a result the amplitude, H, of the reflected sound wave monitored on the screen, now decreases and becomes lower than the initial one, H_o, yielding positive damage values.

3.4 The ultrasonic determination of concrete fracture strength

Many researchers, Facaoaru [13] and Popovics [14], have introduced relations which correlate the strength of concrete with the velocity of ultrasonic waves and have constructed appropriate nommograms for this purpose.

Prassianakis [15] developed a relation between the compressive strength, σ_f, and the ultrasonic longitudinal waves velocity, c_ℓ, for cylindrical concrete specimens. After the regression analysis a model, eq. (6), out of the total developed models, was selected for the determination of compression strength for cylindrical specimens.

$$\sigma_f = e^{\left(9{,}810 - \frac{17{,}713}{c_l}\right)}, \qquad R^2 = 0{,}969 \quad \text{and} \quad F = 124{,}132 \tag{6}$$

where R^2 is the multiple regression correlation coefficient and F the checking coefficient.

The method used for the estimation of the model parameters is the least squares (regression analysis). All calculations and controls were carried out using the software program SPSS release 8.0. Thus, in a series of cylindrical specimens, first the velocity of longitudinal waves was evaluated and then these specimens were tested in compression loading parallel to the direction of rodding and finally their fracture stress was evaluated. The variation of concrete fracture compressive strength σ_f versus the ultrasonic velocity c_l, is shown in Fig. 9(b). So, from pre-constructed nommograms such as this one, for any type of concrete, its fracture strength by measuring only the velocity of ultrasonic waves can be determined.

4. NDT and Fracture Mechanics

The NDT methods would not have so great value if the science of Fracture Mechanics (FM) had not developed.

All structures contain flaws (defects, inherent inclusions and porosity). Every manufactured item contains some sort of discontinuity; impurities and some sort of artifact that guarantees the item will perform at less than optimum. But in the question how much less, only the NDT together with FM can give the answer.

The discipline of FM provides the quantitative relationships, between stress, flaw size and toughness and examines the critical conditions under which the failure of materials, which usually begins from regions of discontinuities where stress concentration exists, takes place.

The materials microscopic or macroscopic discontinuities can be located and determined in time, by the help of NDT methods. Furthermore their influence on materials strength can be studied in detail by the aid of FM.

Information obtained using NDT methods serve as an input to FM calculations in order to predict the remaining life of a component. Thus, using NDT methods the failure of the materials and constructions can be anticipated or even avoided, Prassianakis [3]. So, the NDT methods can be constituted not only a useful but also a unique tool for studying FM problems.

5. Conclusions

From the previously mentioned investigations comes out the following very important and useful conclusions.

The NDT is an excellent tool through the human gender evolution for the execution of the materials quality control. The NDT was constituted the unique way of testing materials in far antiquity. The high level of knowledge and experiences of ancient Greeks in the field of standardization, testing and certification of materials, goods and products was also presented. A well-organized quality control, based on NDT methods, was applied using their five senses: sight, touch hearing, smell and taste.

In nowadays the NDT is applied in a different than in antiquity, modern way offered for any material testing. Using NDT methods not only the defects of materials but also many from their mechanical properties are determined. Thus, using ultrasounds the acoustic attenuation coefficient α, the dynamic moduli of elasticity E', G', ν', the damage parameter D, the fracture strength σ_f, and the order of singularity λ can be determined.

It is absolutely sure that it would not be possible to create all the important and magnificent human technical achievements of nowadays, if such an evolution on the area of NDT, as well as on the area of FM, the two new disciplines that keep pace, had not taken place.

The previous mentioned results together with the ability of the ultrasonic method to determine the discontinuities and defects of the materials without any influence on their future uses make finally the NDT method of ultrasounds not only a powerful, but also a unique scientific tool for the study of FM problems.

All these confirm the opinion that as in the antiquity, so in nowadays, in well organized with developed culture societies developed technology also is observed. Culture and technology that is to say keep pace. It would not be possible to achieve great work of humanity in the antiquity, which are saved up today, if the constructors of that period not used standards and technical specifications, as on the other hand happens in nowadays.

Without NDT it was not possible to use safely all known super-constructions and high technologies, which are used around the world in nowadays. Consequently the NDT constitute an indispensable and unique tool for the development and survival of a community.

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